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BTEC & CGLI
GUIDANCE FOR STUDENTS

Contents

BUSINESS AND TECHNICIAN EDUCATION COUNCIL

National Certificate in Telecommunications

Sets of model questions and answers for Business and Technician Education Council (BTEC) units are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits for questions are shown, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the questions are not representative of questions set by any particular college.

BTEC: LINES II

The questions in this paper are based on the BTEC's standard unit U81/755. Students are advised to read the notes above

Q1 (*a*) *What is the purpose of large companies having corporate objectives?*

(*b*) *List typical corporate objectives of a large telecommunications company.* (*3 min*)

A1 (*a*) The purpose of a company having corporate objectives is to outline broadly the parameters within which a company is to operate as a whole.

(*b*) Typical corporate objectives of a large telecommunications company would be:

(*i*) the provision of a sound and efficiently engineered system,
(*ii*) the provision of a suitable return on capital invested in the company,
(*iii*) the provision of good staff relations with employees, and
(*iv*) the survival of the company.

Q2 *A major manufacturing company considers the possibility of introducing a new product. What business activities will be involved before the company can take a final decision to proceed with the manufacture of the product?*

State typical departments which would be involved in the process. (*5 min*)

A2 Research would have to be carried out to determine the size of the market for the product, the possible extent of ongoing demand and the likelihood of competition from other companies. These activities would be the responsibility of the company's marketing department.

The introduction of new skills as a result of the new product, production line techniques and the method of packaging would be the responsibility of the technical department.

Presentation of the finished product would be the responsibility of the sales department.

The level of production and the estimated cost of the finished product would need to be determined by the planning department.

All these activities would be required before a final decision can be made by the company.

Q3 *What would an average customer expect from a large telecommunications company, in terms of everyday service?* (*3 min*)

A3 Typical customer expectations would be: maximum value for money, immediate installation of new telephone stations, fast and accurate connections to called parties, satisfactory two-way conversation, immediate repair of any service breakdown no matter how minor the breakdown.

Q4 *Complete the following:*

$$\frac{\textit{work required to obtain objectives of system}}{\textit{total input of resources to system}} = ? \quad (\textit{1 min})$$

A4 System efficiency.

Q5 *Explain the term dBm and its use in telecommunications.* (*5 min*)

A5 In telecommunications, the performance of many systems is measured by the power ratio; that is,

$$\frac{\text{power out}}{\text{power in}}.$$

This ratio gives the power gain (or loss) of the system:

$$\text{power gain,} \quad A_{\text{p}} = \frac{\text{power out}}{\text{power in}}.$$

It is more convenient to express this power ratio in logarithmic form, and the unit used for the logarithm of a power ratio is the *bel*; thus

$$A_{\text{p}} = \log_{10}\frac{\text{power out}}{\text{power in}}\ \text{bel}.$$

In telecommunications, the bel is too large a unit. Therefore a power ratio is expressed in terms of a tenth of a bel; that is, a *decibel* (dB).

Therefore,

$$A_p = 10 \log_{10} \frac{\text{power out}}{\text{power in}} \text{ dB}.$$

Thus the decibel is used to represent the ratio of the output to the input power. It can also be used to represent the level of a signal by reference to a known signal level. The reference level usually used is the milliwatt, and this is indicated by dBm. Thus, a signal level of 30 dBm would represent

$$1000 \times 1\,\text{mW} = 1\,\text{W}.$$

Q6 *Explain the need for forecasting.* (*2 min*)

A6 In any business, the available resources must match the demand for the company's services or products, and therefore there is a need to know where and when demand will arise and the extent of the requirements. Forecasting the demand will enable the company to have the necessary manpower, plant, equipment and finance available at the required time, and thus avoid any delays in meeting the demand when it occurs.

Q7 *Compare the effects of underestimating with overestimating in project planning.* (*3 min*)

A7 Underestimating results in a company being unable to meet the requirements of its customers, to meet increased installation and manpower costs and results in the undermanning of a project. This all leads to customer dissatisfaction and the possible loss of future orders.

Overestimating results in increased costs arising from equipment and plant lying idle for long periods, and results in the overmanning of projects. Providing customers with inflated estimates may lead to customers going elsewhere.

Q8 *A suburb has 400 tenancies. The current penetration factor for telephone lines is 0·82 and the target factor is 1·05. Determine*

(*a*) *the current number of tenancies with telephone service, and*
(*b*) *the targeted number of telephone lines in service within the suburb.* (*3 min*)

A8 (*a*) $\text{Penetration factor} = \dfrac{\text{number of connections}}{\text{number of tenancies}}.$

Therefore, the number of connections

$$= 0{\cdot}82 \times 400 = \underline{328}.$$

(*b*) Targetted number of connections

$$= 1{\cdot}05 \times 400 = \underline{420}.$$

Q9 *In forecasting, what financial factors tend to influence the delay of plant provision?* (*2 min*)

A9 The financial influencing factors are

(*a*) existing high interest rates,
(*b*) high values of plant depreciation, and
(*c*) high values of plant maintenance.

Q10 *What is the main influencing factor in*

(*a*) *the growth of local line plant,*
(*b*) *the growth of junction line plant.* (*2 min*)

A10 (*a*) The growth in local line plant is directly related to the growth in the number of customers.

(*b*) The growth in junction plant is directly related to the growth in the flow of telephone traffic between exchanges.

Q11 *Define the term 'cable'.* (*2 min*)

A11 A cable is an assembly of conductors insulated from one another and enclosed in a common binding or sheathing, and having some degree of flexibility.

Q12 *Define the term 'cable pair'.* (*2 min*)

A12 A cable pair comprises two conductors, insulated from each other, and associated to form part of a communication channel or channels.

Q13 *List the primary and secondary coefficients of a metallic cable.* (*2 min*)

A13 Primary coefficients: Resistance
Inductance
Conductance
Capacitance

Secondary coefficients: Characteristic impedance
Attenuation coefficient
Phase change coefficient
Velocity of propagation.

Q14 *A transmission line has an inductance of 120 mH and a capacitance of 0·3 μF. Assuming a very-high-frequency signalling system, determine the characteristic impedance of the line.* (*3 min*)

A14 Characteristic impedance,

$$Z_0 = \sqrt{\left(\frac{L}{C}\right)},$$
$$= \sqrt{\left(\frac{120 \times 10^{-3}}{0{\cdot}3 \times 10^{-6}}\right)},$$
$$= \sqrt{(4 \times 10^5)},$$
$$= \underline{632\,\Omega}.$$

Q15 *What is the purpose of the loading of a transmission cable?* (*1 min*)

A15 The primary aim of loading a transmission cable is the reduction of signal attenuation. Loading also reduces distortion effects of the line on the signal waveform.

Q16 *List the types of loads and stresses to which poles supporting an overhead transmission line may be subjected.* (*1 min*)

A16 Poles are subjected to bending and compressive stresses. These are due to the weight of the lines, the pressure of the wind on the lines, and the additional weight of ice forming on the lines.

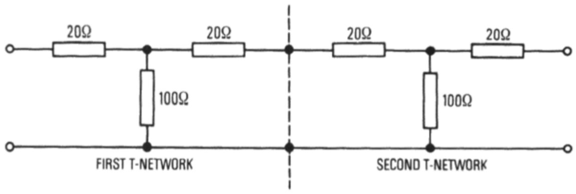
Q17 *The pull on a pole is given as 428 N and the effective height of the pole is given as 7·8 m. Assuming that the pole is not stayed, determine the bending moment.*

A17 Bending moment = pull on pole × height of pole,

$$= 428 \times 7{\cdot}8,$$
$$= 3{\cdot}34\,\text{kN m}.$$

Q18 *A transmission line is represented by a number of sections. Each section is considered to have a total series impedance of 40 Ω, and a shunt impedance of 100 Ω. Assuming that each section can be represented by a T-network, draw a circuit diagram representing the line showing at least two sections.* (*5 min*)

A18

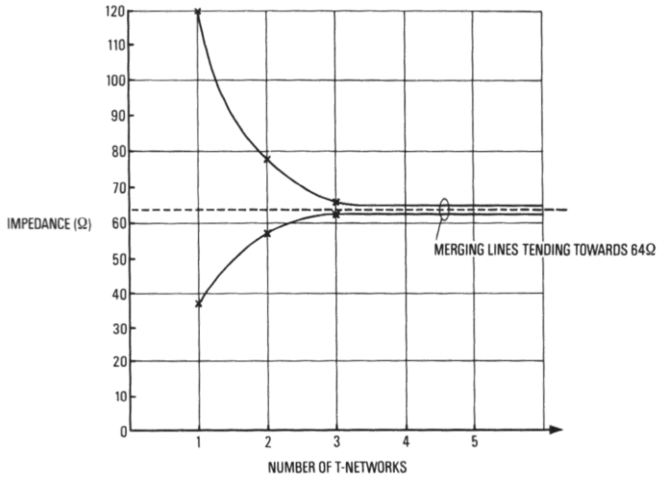


Q19 *A transmission line is represented by a number of T-networks. In a DC test, the following readings were obtained:*

Number of T-networks in test	*Readings (ohms)*	
	Short circuit	*Open circuit*
1	*37*	*120*
2	*57*	*78*
3	*63*	*66*

Plot a graph of impedance against the number of T-networks and explain how the characteristic impedance of the line can be obtained. *(8 min)*

A19 The plot is shown in the sketch.



The two plots tend to merge towards the value of the characteristic impedance. In this case, the characteristic impedance of the line is 64 Ω.

Q20 *List the factors that influence the resistance of a conductor.* *(2 min)*

A20 The cross-sectional area of the conductor.
The conductivity of the conductor.
The temperature of the conductor.
The frequency of the current flowing in the conductor.

Q21 *What considerations would be necessary when the most economic method of line plant provision is not obvious to the planning engineer.* *(3 min)*

A21 When the most economic method of plant provision is not obvious, it becomes necessary to assess the cost of all the alternatives. Apart from capital costs, maintenance, depreciation and operating costs would need to be considered, as well as interest on the capital used.

Q22 *In project planning, what is a straight-line diagram?* *(2 min)*

A22 A straight-line diagram in project planning is a simple diagram setting out the existing and proposed cable network for a project in terms of the cabling network design, cable sizes, use of flexibility points, etc. The diagram is drawn to approximate geographical proportions and the cables are represented as straight lines.

Q23 *It is proposed to link a customer's telephone line to a local exchange by means of a number of cable sections. The length of each cable section, together with the loop resistance per kilometre, and the attenuation per kilometre, is tabulated below. Determine the loop resistance and the attenuation of the proposed link. If the limits on attenuation and loop resistance for the particular exchange are 10 dB and 1000 Ω, comment on the results.*

(8 min)

Cable section	*Length (km)*	*Loop resistance (Ω/km)*	*Attenuation (dB/km)*
1	*0·72*	*280*	*2·5*
2	*2·2*	*270*	*2·2*
3	*1·4*	*170*	*1·7*

A23
Section 1:
Loop resistance $= 0{\cdot}72 \times 280 = 201{\cdot}6\,\Omega$.
Attenuation $= 0{\cdot}72 \times 2{\cdot}5 = 1{\cdot}8$ dB.

Section 2:
Loop resistance $= 2{\cdot}2 \times 270 = 594\,\Omega$.
Attenuation $= 2{\cdot}2 \times 2{\cdot}2 = 4{\cdot}84$ dB.

Section 3:
Loop resistance $= 1{\cdot}4 \times 170 = 238\,\Omega$.
Attenuation $= 1{\cdot}4 \times 1{\cdot}7 = 2{\cdot}38$ dB.

Therefore, the total loop resistance

$$= 201{\cdot}6 + 594 + 238 = \underline{1033{\cdot}6\,\Omega},$$

and total attenuation

$$= 1{\cdot}8 + 4{\cdot}84 + 2{\cdot}38 = \underline{9{\cdot}02\text{ dB}}.$$

From the results, the attenuation is within the prescribed limit of 10 dB, but the loop resistance of the proposed line exceeds the prescribed limit of 1000 Ω.

Q24 *Why is project planning desirable?* *(3 min)*

A24 Project planning ensures that services are provided to customers as efficiently and as economically as possible. It also ensures that service can be given to customers at the time required in order to avoid delays with the consequent loss of a good public image.

Q25 *In the scheduling of a project, what is the limitation in the use of bar charts? What alternative chart could be used?* *(2 min)*

A25 Bar charts are ideal for projects which have sequential activities, but they cannot display any parallel activities. An alternative chart which can display parallel activities is the critical path analysis (CPA) chart.

Q26 *The insulation resistance of a 3·2 km cable is given as 984 MΩ. Determine the insulation resistance per kilometre.* *(2 min)*

A26 Insulation resistance per kilometre

$$= 984 \times 3{\cdot}2 = 3148{\cdot}8\text{ M}\Omega/\text{km}.$$

Q27 *(a) List the effect on service to the customer for the following local line faults:*

(i) severed cable,
(ii) high-resistance joint,
(iii) short circuit, and
(iv) ingress of moisture.

(b) For each of the fault conditions, state the test condition at the test desk. *(5 min)*

A27 (*a*) (*i*) Severed cable: No dial tone at calling station. Continual ring tone would be returned to any caller.
(*ii*) High-resistance joint: Noisy line. Dialling faults.
(*iii*) Short circuit: Permanent engaged tone to caller. Permanent dial tone or 'dead' line to user. (Condition is dependent on short circuit: full short circuit gives dead line; resistive short circuit gives permanent dial tone.)
(*iv*) Ingress of moisture: Noisy line. Dialling faults.

(*b*) (*i*) Severed cable: Open circuit, or infinite loop resistance.
(*ii*) High-resistance joint: High loop resistance.
(*iii*) Short circuit: Low loop resistance.
(*iv*) Ingress of moisture: Low insulation resistance or partial earth on the A-leg or B-leg of the line.

Q28 *In a Varley test, the following results were obtained on a 4·1 km telephone line.*

Loop resistance: $840\ \Omega$.
Varley reading: $320\ \Omega$.

Equal ratio arms were used and the faulty wire was assumed to have the same resistance as any good wire in the cable under test. Determine the distance to the fault. *(3 min)*

A28 Distance to the fault

$$= \left(1 - \frac{\text{Varley reading}}{\text{loop resistance}}\right) \times \text{length of line},$$

$$= \left(1 - \frac{320}{840}\right) \times 4{\cdot}1,$$

$$= \underline{2{\cdot}54\ \text{km}}.$$

Q29 *What are the advantages of pressurising cables?* *(3 min)*

A29 Pressurised cables ensure a higher standard of insulation than non-pressurised, the cable core is further protected against the ingress of moisture, cable sheath faults become apparent immediately the sheath is damaged and a means is provided for locating the cable sheath fault before electrical faults develop. The reduction of electrical breakdowns in cables improves the service.

Q30 *What are the main causes of cable faults?* *(2 min)*

A30 The main causes of cable faults are damage caused by contractors and road-works undertakers, below-standard installations and corrosion.

Q31 *Define the term 'crosstalk'.* *(2 min)*

A31 Crosstalk is the transfer of energy from one cable circuit to another. It results in overhearing on audio circuits.

Q32 *(a) Identify the diagram shown in Fig. 1.*
(b) Indicate the critical path. *(3 min)*

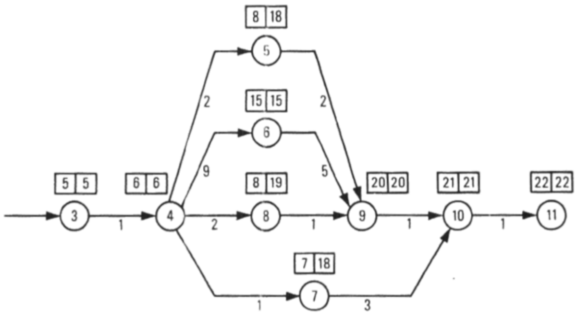
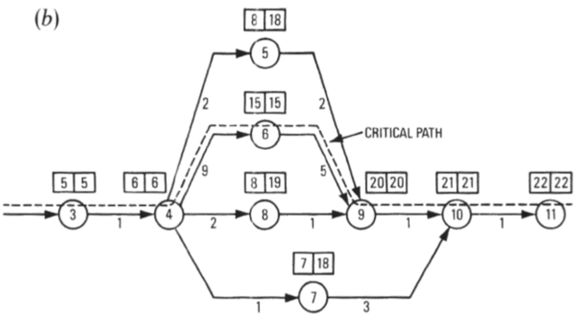


Fig. 1

A32 (*a*) Critical-path analysis (CPA) chart.

(*b*)



Questions and answers contributed by N. C. Webber

CITY AND GUILDS OF LONDON INSTITUTE

Telecommunications Technicians (New) Scheme

The following questions are from examination papers set for the City and Guilds of London Institute's (CGLI's) new 271 Telecommunications Technicians Scheme, and are reproduced with the permission of the CGLI. The answers given have been prepared by independent authors. Answers to some questions are occasionally omitted because of insufficient space. Students studying BTEC courses may find that these questions are useful for revision.

CGLI: SWITCHING T5 OPTION (1986)

Students were required to answer any five questions. The time allowed was three hours. Students are advised to read the notes above

Q1 (*a*) *For telephone traffic in delay call systems*

(*i*) *state the erlang formula for calculating the probability of a call being delayed*
(*ii*) *list three conditions for the formula in* (*i*) *to be valid*
(*iii*) *apply the formula to show that, with single server systems, the probability of delay is numerically identical with the average busy hour traffic in erlangs.*

(*b*) *The average holding time of a common translator is 300 ms. Calculate*

(*i*) *average busy hour traffic in erlangs, given that the mean delay of all calls is 50 ms*
(*ii*) *mean delay of the delayed calls.*

A1 (*a*) (*i*) For a delay call system with many channel servers, the probability of a call being delayed is given by

$$P(>0) = \frac{\dfrac{A^N}{N!}\dfrac{N}{(N-A)}}{1 + A + \dfrac{A}{2!} + \cdots + \dfrac{A^{(N-1)}}{(N-1)!} + \dfrac{A^N}{N!}\dfrac{N}{(N-A)}},$$

where N is the number of servers and A is the traffic offered in erlangs.

(*ii*) The conditions for the formula in part (*i*) to be valid are:

1 Full availability conditions must exist so that a queue cannot be formed when there are free channels available.

2 The maximum number of calls in progress simultaneously is N and calls arriving when all N channels are occupied form a queue and wait in the order of their arrival for free channels.

3 The queue discipline must impose assumptions on the number of sources, X, and it is further assumed that $X \geqslant N$. To simplify the mathematics involved in analysis, in the majority of queuing problems, X is taken as infinite.

4 In a waiting system, the traffic offered to the system must not exceed the traffic carrying capacity of the channels; that is, $A < N$ where A is the traffic offered in erlangs and N is the number of channels. If this condition is not fulfilled, the queue grows to an infinite size.

[*Tutorial Note:* Only three conditions were requested.]

(*iii*) For a single server system, $N = 1$.
Substituting $N = 1$ in the formula in part (*i*) gives

$$P(>0) = \frac{\dfrac{A^1}{1!}\dfrac{1}{(1-A)}}{1 + \dfrac{A^1}{1!}\dfrac{1}{(1-A)}},$$

$$= \frac{\dfrac{A}{1-A}}{1 + \dfrac{1}{1-A}},$$

$$= A.$$

Hence, for a single-server system, the probability of delay is numerically identical with the average busy-hour traffic in erlangs.

(*b*) (*i*) The mean delay of calls,

$$M = P(\geqslant 0)\frac{H}{N-A},$$

where H = average holding time, and N = number of servers.

For a single-server system, $P(\geqslant 0) = A$, and $N = 1$.

$$\therefore \quad M = \frac{AH}{1-A}.$$

Given that $M = 50$ ms and $H = 300$ ms,

$$50 = \frac{A \times 300}{1-A},$$

$$\therefore \quad 50\text{–}50A = 300A.$$

$$\therefore \quad 350A = 50.$$

$$\therefore \quad A = \frac{50}{350},$$

$$= \frac{1}{7},$$

$$= \underline{0{\cdot}143 \text{ erlangs}}.$$

(*ii*) The mean delay of the delayed calls,

$$M = \frac{H}{N-A}.$$

Substituting values,

$$M = \frac{300}{1 - 0{\cdot}143}\text{ms}$$

$$= \underline{350 \text{ ms}}.$$

Q2 *For a national trunk network*

(*a*) *explain why the two-wire switched network is restricted to two links*
(*b*) (*i*) *with the aid of a labelled diagram describe the transit network switching and transmission plan*
(*ii*) *explain why this plan is known as the 'basic network'*
(*iii*) *list two advantages provided by 4-wire switching at the transit exchanges.*

Q3 *For the CCITT world numbering plan explain*

(*a*) *the need to provide every customer with a unique number*
(*b*) *how and why numbering zones are provided*
(*c*) *how country codes are allocated within the zones*
(*d*) *the significance of telephone density on the code allocated to a particular country*
(*e*) *the restriction that is placed on national numbers by the plan*
(*f*) *the essential features of a typical international telephone number.*

A3 (*a*) For the CCITT world numbering plan, it is essential to provide every customer with a unique number in order that a customer may be uniquely identified and that telephone customers world-wide may set up calls automatically to one another without the need for operator intervention.

(*b*) Under the plan, the world is divided into nine areas known as *world numbering zones* and each zone has been allotted a digit from 1–9.

The areas covered are as follows:

World numbering zone 1 (Integrated number plan)
North America and the West Indies excluding Cuba

World numbering zone 2	The African continent
World numbering zone 3 and zone 4	Europe, divided into two world numbering zones
World numbering zone 5	South America and Cuba
World numbering zone 6	Australasia, the Pacific Islands, the East Indies including Thailand
World numbering zone 7	USSR
World numbering zone 8	The Far East
World numbering zone 9	The Middle East and the Indian sub-continent

Numbering zones are provided in order that the initial digit (1–9) identifies the particular zone of the world.

(*c*) Countries within the zones are allocated country codes, which can be single digits for large countries (for example, USSR), two digits for medium-size countries (for example, Great Britain is 44) and three digits for small countries (for example, Tonga is 676).

(*d*) The code allocated to a particular country is dependent on the telephone density for that country compared with other countries within the same zone. For example, within the African continent (world numbering group 2), Ghana has the country code 233 whereas the Republic of South Africa has the two-digit code 27. This gives a larger range of telephone numbers for countries with the highest telephone densities.

(*e*) The numbering plan allows for a maximum size of international number of 12 digits (excluding the international prefix); however, as the country code can be one to three digits, this can place a restriction on the ultimate number of telephone customers that a country can have under the plan. For example, if a country has a three-digit country code, then the ultimate number of telephone customers will be 10^9, whereas a country with a two-digit country code will be 10^{10}.

(*f*) A typical UK customer's international telephone number is +44 1 246 8026. This is made up as follows:

+—represents the international dialling prefix, which varies from country to country.
44—identifies the required country (UK).
1—identifies the numbering group (London area). The initial '0' is not dialled by callers abroad.
246—identifies the required exchange (within the London area).
8026—identifies the required number.

Q4 *For a typical controlling register-translator*

(*a*) *list five main facilities*

(*b*) *describe, with the aid of a block diagram, the principle of operation*

(*c*) *explain how service is maintained when a common translator develops a fault.*

Q5 *For a telephone exchange switching system employing stored-program control (SPC) principles*

(*a*) *sketch and label a block diagram showing the essential items in the switching and control areas*

(*b*) *explain, in general terms, how the speech path for a local call is established by the control*

(*c*) *explain the importance of system security and give an example where this is taken into account in the control area.*

Q6 *For the CCITT international transmission and switching plan*

(*a*) *state how the classes of centre-du-transit (CT) trunk exchanges are classified*

(*i*) *indicate which of these provides access to national telephone networks*

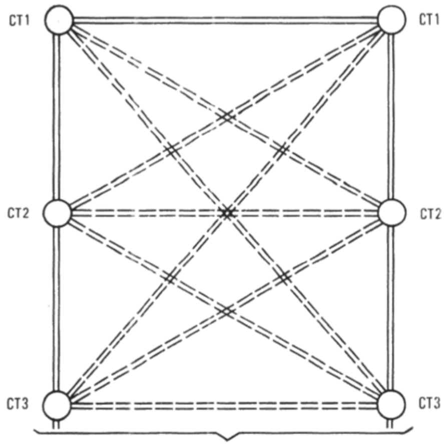
(*ii*) *with the aid of a sketch describe how these classes of exchanges are interconnected*

(*b*) *explain how the circuit stability requirement of 'multi-link' international connections is achieved*

(*c*) *explain how the CT rank of an exchange can vary on different international connections.*

A6 (*a*) (*i*) The CCITT international transmission and switching plan is based upon a 4-wire switching network and has been designed to be compatible with the national transit network. There are three classes of *centre-du-transit* (CT) trunk exchange: CT1, CT2 and CT3. A CT3 exchange normally only connects international circuits to national networks, while CT1 and CT2 exchanges, in principle, connect only international circuits together. There is no essential difference between a CT1 and a CT2 exchange; the CT1 exchanges are intended to be fully interconnected, whereas the CT2 exchanges are not.

(*ii*) The sketch indicates how the classes of exchanges are interconnected.



Every CT3 exchange is connected to at least one CT2 exchange and every CT2 exchange is connected to at least one CT1 exchange. If the CT1 exchanges are fully interconnected, this arrangement would ensure that any CT3 would be connected to any other CT3 exchange via no more than five circuits; that is, CT3–CT2–CT1–CT1–CT2–CT3.

However, CT1 exchanges may not be fully interconnected in practice and the sub-routings CT1–CT1–CT1 or CT1–CT2–CT1 are permitted. With this relaxation, the maximum number of international circuits in a connection could be six.

(*b*) See, Q9(*c*), CGLI: Switching T5 Option (1985), Supplement, Apr. 1986, p. 22.

(*c*) The CT rank of an exchange can vary, depending on type of call. For example, for a call between customers in Paris and London, the Paris and London exchanges function as CT3 exchanges.

For a call from a Paris customer to a New York customer, established via London, London is a CT2 exchange, Paris and New York being CT3 exchanges. For a call routed Brussels–Paris–London–New York–Bogotá–Lima, London and New York are CT1 exchanges, Paris and Bogotá are CT2 exchanges and Brussels and Lima are CT3 exchanges. Whilst this last routing is unlikely, it does illustrate that the same London–Paris circuit could have been used for all these connections, so that one circuit could be CT3–CT3, CT3–CT2 or CT2–CT1, according to the class of connection.

Q7 (*a*) *For a subscriber trunk dialling (STD)*

(*i*) *state* FOUR *main facilities*

(*ii*) *define 'local call area' and 'dependent charging group'*

(*iii*) *explain the need for charging groups and with a labelled sketch show how they are arranged for both local and STD timed calls.*

(*b*) *With the aid of a trunking diagram, describe the routing of incoming STD calls in a non-director area.*

A7 (*a*) (*i*) For a subscriber trunk dialling (STD) network, four main facilities are:

Routing the ability to provide translation and routing of calls, automatically.
Charging the ability to record call charges against calling customers automatically.
Customer identification the ability for customers to have a unique national number.
Flexibility the ability for the network to meet future growth and changes in requirements.

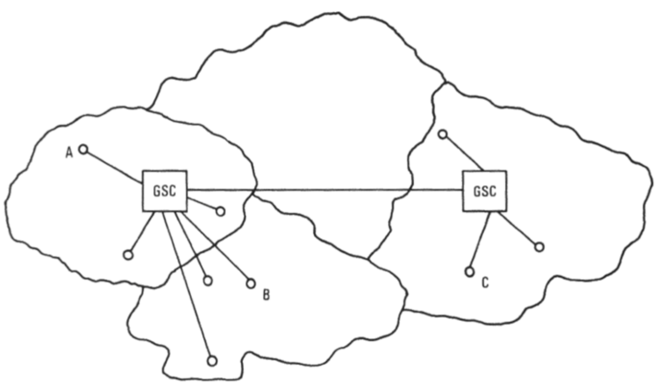
(*ii*) The *local call area* can be defined as the area containing the home charge group and the adjacent charge groups; that is, calls made from the home charge group to the adjacent charge groups are charged at the local call rate. There are a few instances where the adjacent charge group may not be in the local call area; for example, when adjacent groups are separated by mountains.

A *dependent charging group* is a charge group which does not have its own group switching centre (GSC), but is dependent on a GSC in a neighbouring charge group.

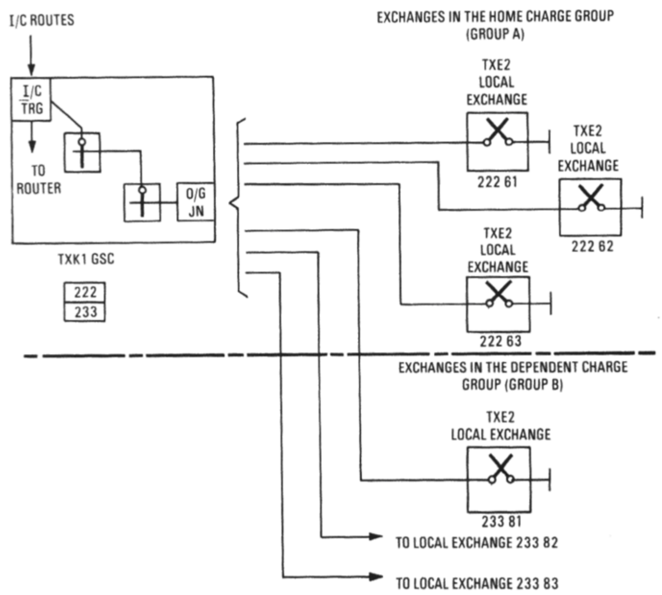
(*iii*) In principle, the charge for a call is determined by the straight-line distance between the originating and terminating exchange. In order to avoid increasing the size of the numbering group codes, exchanges are formed into groups known as *charging groups*. Each group has a fixed point known as the call charge point and all trunk call charges are calculated on the straight-line distance between call charge points of the originating and objective charge groups.

Sketch (*a*) shows examples of local calls and trunk calls.

In sketch (*a*), a call from exchange A to exchange B is to an adjacent charge group and is charged at the local call rate even though it is routed via the GSC. A call from exchange A to exchange C is to a non-adjacent charge group and it is charged at a trunk rate.



(*a*)



I/C: Incoming
I/C TRG: Incoming transmission relay group
O/G JN: Outgoing junction

(*b*)

(*b*) Sketch (*b*) shows a simplified trunking diagram of the routing of incoming STD calls to a non-director area.

For sketch (*b*), the TXK1 GSC unit serves a non-director area of two charging groups, A and B. These groups are identified by the national number group codes 222 and 233 respectively. A distant customer would be routed to the GSC when dialling 222 or 233; however, the originating GSC provides for different call charges where necessary. At the GSC, the next two digits identify the objective exchange.

Q8 (*a*) *Explain the term stored-program control (SPC).*

(*b*) *Describe, with the aid of a block diagram, the organisation of an SPC processor.*

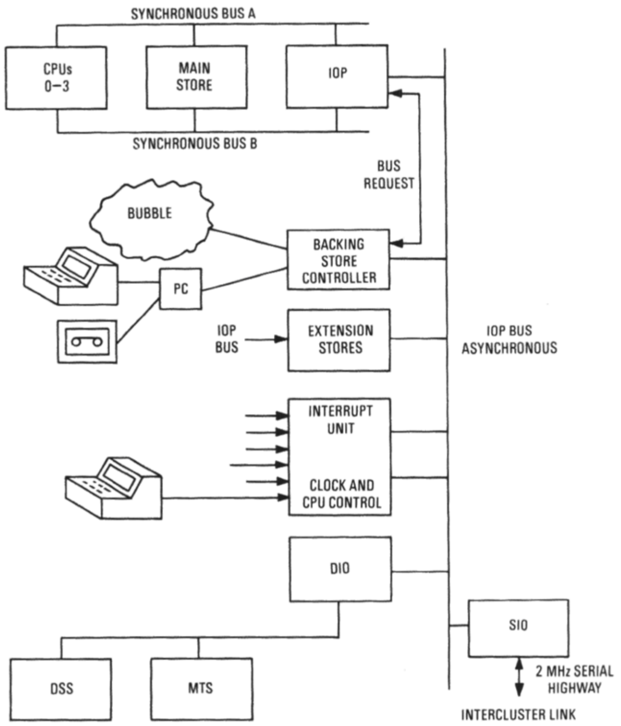
(*c*) *When considering a computer dedicated to the control of a telephone exchange explain*

(*i*) *the significance of the software*

(*ii*) *the difference between this computer and a general purpose computer.*

A8 (*a*) The term *stored-program control* (SPC) is used to describe a method of telephone exchange control. An SPC exchange has a program store which is readily accessible and easily modified, to which application is made for instructions for setting up calls.

(*b*) A block diagram of an SPC processor designed for a digital exchange is given in sketch (*a*).



(*a*)

Groups of up to four central processing units (CPUs) are connected together by two highways, along with their storage and external input/output peripherals, to form a multiprocessor. Multiprocessing allows CPUs to work simultaneously in common store, with management provided by a real-time operating system. A group of up to four CPUs tightly coupled is known as a *cluster*. A small digital exchange can contain one cluster with a minimum of two CPUs; a large digital exchange can contain eight clusters with a maximum of 32 CPUs.

The software comprises the real-time operating system and the application software suite.

There are two types of exchange peripheral access: direct input/output (DIO) and serial input/output (SIO). The DIO is used to communicate with application hardware in a large exchange. The SIO is used for inter-cluster communication in a large exchange

and for communication to applications hardware in a small exchange.

The modules in the system communicate via two highways: the synchronous and the asynchronous highways. The synchronous highway is high speed and is used for the transfer of data between CPUs and the main store. The asynchronous highway is used for the transfer of data to modules with slower response time. Access is via the input/output processor (IOP).

There are three stores: main, backing and extension store. The main store contains permanent data and programs; for example, the call processing subsystem. The backing store is bubble memory containing versions of processes and a working area for transfer of data. The extension store contains reserved data and program which is non-critical.

The interrupt unit contains the hardware necessary to enable an external event to interrupt processing on the CPUs, and the system clocks.

For security, the IOP, interrupt units, backing store, peripheral controllers, SIO and DIO are duplicated. This is not shown in sketch *(a)*.

(c) *(i)* For a digital telephone exchange processor, software falls into one of two categories:

Applications programs These perform the functions to make the hardware perform as a telephone exchange; that is, it contains the information necessary to output correct operations for given inputs; to switch a connection through the digital switch for example. The application program varies for each installation.

Real-time operating systems These programs enable the internal working of the processor and the interfacing with the application software. The operating system is the same for each installation since it controls the processor and not the hardware.

Both the application programs and the operating system programs are written in units called *processes*. This keeps the programs in small blocks and aids the control and location of corrupted software.

The processing modular programming causes more work on the system and requires a more complicated operating system. Processes are run in order of priority, each process is allocated a priority number and each process is independent and secure from access from other processes.

(ii) The main differences between the exchange processor and a general purpose computer are as follows.

A general purpose computer is normally designed to do calculations, based on programs. It usually is designed to do only a limited number of processes at one time and its units are not duplicated.

An exchange processor differs from a general purpose computer because it is task oriented and can undertake a number of different processes at the same time. It also has to be highly reliable. In the event of one part of the processor failing, other parts of the processor can take over. In addition to this, its multiprocessor design enables it to be increased in size to cope with growth in connections and call processing, during the life of the exchange.

Q9 *(a) Define*

(i) annual charges
(ii) present value of annual charges.

(b) An average of one erlang of busy hour telephone traffic is to be carried from exchange A to exchange B at a grade of service not worse than 0·005.

An existing outgoing tandem route at exchange A operates with an incremental traffic figure per tandem junction of 0·7 erlangs. Tandem route circuit cost is estimated to be 20% more than the direct route circuit cost.

Determine whether the most economic method of routing this traffic is by a direct route or by the tandem route.

A9 *(a) (i)* Annual charges are the sum of individual charges for interest, depreciation, maintenance and operating costs over a year.

For a project, it is assumed that sums invested in it involve a commitment in the form of annual interest on the sum concerned.

The annual charge for depreciation is assumed as uniform contributions to a sinking fund, which, accumulating at compound interest at the long-term rate over the life of the plant, would reach an amount equal to the original capital cost of the item less its residual value if any.

The annual charge for maintenance is taken as the average annual cost of maintaining it in serviceable condition during its life.

When a project requires staff to operate equipment, then those operating costs are also expressed as an annual charge.

(ii) When it is necessary to compare the costs of two different schemes, it is often found that capital expenditure is envisaged at different times for the alternative schemes. It follows that the annual charges will not be constant and costs merely in the form of annual charges cannot be used for comparison.

In order to make a comparison of costs, the annual charges are capitalised at a common date; the capitalised value is known as the *present value of annual charges* (PV of AC).

(b) For the tandem route:

If the incremental traffic per trunk on the tandem route is 0·7 erlangs and the traffic offered to the route is 1 erlang, then two trunks would have to be provided to carry the additional traffic.

If the cost per trunk is £x then two trunks would cost £2x.

For the direct route:

When $A = 1$,

$$0{\cdot}005 > \frac{\dfrac{1^N}{N!}}{\displaystyle\sum_0^N \frac{1^x}{x!}} = \frac{\dfrac{1}{N!}}{\displaystyle\sum_0^N \frac{1}{x!}}.$$

By using Poisson's approximation

$$0{\cdot}005 > \frac{1}{eN!} \quad (\text{where } e = 2{\cdot}718).$$

$$\therefore \quad 0{\cdot}0136 \times N! > 1.$$

$$\therefore \quad N! > 73{\cdot}5.$$

Testing for values of N,

$$4! = 4 \times 3 \times 2 \times 1 = 24.$$

$$5! = 5 \times 4 \times 3 \times 2 \times 1 = 120.$$

Therefore $N = 5$ is the minimum value of N to satisfy $N! > 73{\cdot}5$. Five trunks are required and the total cost would be

$$5 \times \frac{£x}{1{\cdot}2} = £4{\cdot}17x.$$

Therefore the most economic method of routing this traffic is by the tandem route.

Q10 *(a) For international direct dialled (DD) calls, explain*

(i) the importance of conforming to CCITT recommended sending and receiving reference levels
(ii) one method of charging and billing the subscriber for the call
(iii) how operating administrations apportion and collect charges.

(b) Explain how language problems are taken into account when operator assistance is required on an international call.

A10 *(a) (i)* In order to ensure the quality of transmission on an international call, necessary for the correct operation of in-band signalling equipment and for satisfactory transmission level between subscribers, the CCITT transmission plan includes both national and international networks.

The CCITT recommendations for the maximum transmission loss of international connections are stated in terms of *overall reference equivalent* (ORE), expressed in decibels relative to an internationally agreed reference system. ORE includes the electro-acoustic properties of telephone instruments and the electrical properties of local lines (including the transmission bridge in the local exchange). The international transmission plan recognises that each national administration must be free to allocate transmission losses in its own national system. The maximum permitted losses of national systems are expressed in terms of *send reference equivalent* (SRE) and *receive reference equivalent* (RRE) referred to interface points (known as *virtual switching points*) on the international circuit in the CT3 exchange. The maximum loss recommended for SRE is 21 dB and for RRE 12 dB.

CGLI: SWITCHING T5 OPTION (1986) *(continued)*

(*ii*) A method of charging the calling subscriber for the call, as adopted for UK local digital telephone exchanges, is for the charge rate for the call to be determined at the originating local exchange by examination of the country code and area code digits, together with the tariff period (time of the day).

The call accounting subsystem within a digital local exchange times the call as soon as the *called subscriber answer* signal is received until the calling subscriber clears, and calculates the number of metered units to apply to the meter store of the calling subscriber.

The billing of the call is achieved by reading the contents of the meter store and calculating the charges on an off-line billing system. In addition to this method, it is possible for international call details to be itemised and charges for these calls to be presented separately on the bill.

(*iii*) So that administrations can apportion and collect charges for international calls, it is necessary for call-duration times to be calculated together with details of where the call comes from and where the call went to. The CCITT recommends that international accounts be calculated within an accuracy of 2%.

In practice, actual charges raised by administrations are by negotiation, taking into account the levels of traffic each receive and any through-traffic handled.

(*b*) The CCITT international plan covers semi-automatic operation, an important feature of which is the ability to signal the language which an assistance operator should speak when handling the call. The information is conveyed by means of a language digit that must immediately precede the national part of the international number. The CCITT has allocated the following language digits:

1	French	6	
2	English	7	By agreement
3	German	8	
4	Russian	9	Reserved
5	Spanish	0	Automatic (IDD)

It is the practice in all UK international switching centres (ISCs) for the language digit to be inserted automatically by the equipment processing an outgoing international call.

Answers contributed by J. Bush

CGLI: TRANSMISSION T5 OPTION (1986)

Students were required to answer any five questions. The time allowed was three hours. Students are advised to read the notes on p. 5

Q1 A carrier wave $e_c = E_c \sin \omega_c t$ is amplitude modulated to a depth of 50% by a

(*i*) *1 kHz sinusoid*

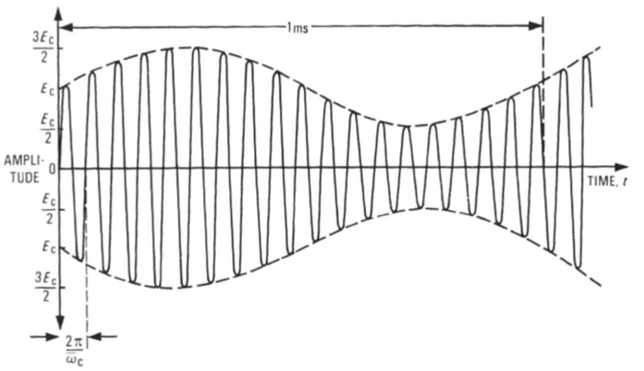
(*ii*) *square wave of period 1 ms.*

(*a*) *Using squared paper carefully sketch the modulated waveforms showing for each waveform the periods of the carrier and the signal.*

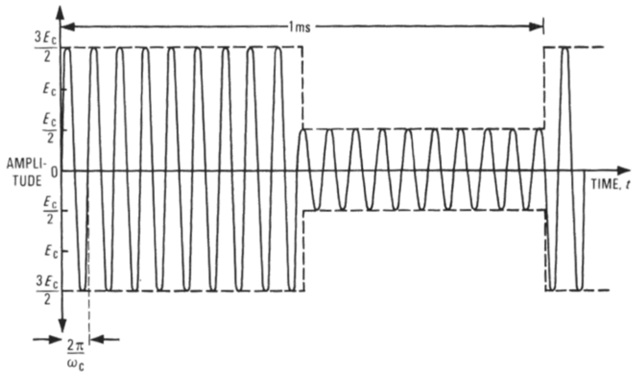
(*b*) *Explain why the bandwidth required by modulating with the sinusoid will be different from that produced by the square wave. Justify your answer.*

(*c*) *Determine the percentage of power saved by having single sideband suppressed carrier (SSBSC) transmission instead of double sideband (DSB) transmission.*

A1 (*a*) Sketch (*a*) shows the carrier modulated by the 1 kHz sinusoid, 50% modulation depth. Sketch (*b*) shows the carrier modulated by the square wave of period 1 ms, 50% modulation depth.



(*a*)



(*b*)

(*b*) The instantaneous voltage of an amplitude modulated signal can be written as:

$$e = \{E_c + v(t)\} \sin(\omega_c t) = E_c \sin(\omega_c t) + v(t) \sin(\omega_c t),$$

where $v(t)$ is the modulating signal and $E_c \sin(\omega_c t)$ is the carrier.

When $v(t)$ is a sinusoid of the form $V_m \sin(\omega_m t)$, the general expression involves the product of $\sin(\omega_c t)$ and $\sin(\omega_m t)$ which, when expanded, gives the terms $\cos\{(\omega_c - \omega_m)t\}$ and $\cos\{(\omega_c + \omega_m)t\}$. The amplitude modulated signal therefore contains components at the carrier frequency f_c and two side frequencies of $(f_c \pm f_m)$. The bandwidth therefore extends from $(f_c - f_m)$ to $(f_c + f_m)$; that is, a bandwidth of $2f_m$.

When $v(t)$ is a square wave of the form:

$$v(t) = \frac{4}{\pi} V_m\{\sin(\omega_m t) + \tfrac{1}{3}\sin(3\omega_m t) + \tfrac{1}{5}\sin(5\omega_m t) + \cdots\},$$

an expansion of the general expression involves the products of $\sin(\omega_c t)$ with $\sin(\omega_m t)$ and all the odd harmonics of v_m up to infinity. Hence there are an infinite number of side frequencies $(f_c \pm f_m), (f_c \pm 3f_m), (f_c \pm 5f_m), \ldots$ etc. The theoretical bandwidth is therefore infinite; in practice, the bandwidth is finite because the amplitudes of the higher-order harmonics become progressively smaller.

(*c*) The total power content of a DSB signal is:

$$P_{DSB} = P_c\left[1 + \frac{m^2}{2}\right] = P_c + \frac{m^2}{2} P_c,$$

where P_c is the unmodulated carrier power,
m is the modulation index, and
$\frac{m^2}{2} P_c$ is the total sideband power.

Hence the power content of an SSBSC signal is:

$$P_{SSBSC} = \frac{1}{2}\left[\frac{m^2}{2} P_c\right] = \frac{m^2}{4} P_c.$$

The relative power content of an SSBSC signal compared to a DSB signal is therefore:

$$\frac{P_{SSBSC}}{P_{DSB}} = \frac{\frac{m^2}{4} P_c}{P_c + \frac{m^2}{2} P_c} = \frac{m^2}{4 + 2m^2}.$$

For 50% modulation depth, $m = 0{\cdot}5$.

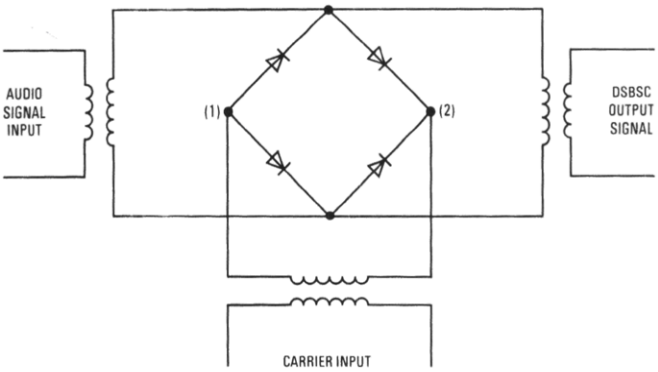
$$\therefore \quad \frac{P_{\mathrm{SSBSC}}}{P_{\mathrm{DSB}}} = \frac{0{\cdot}5^2}{4 + 2(0{\cdot}5^2)} = 0{\cdot}056 = 5{\cdot}6\%.$$

The power saving is therefore $(100 - 5{\cdot}6) = \underline{94{\cdot}4\%}$.

Q2 *For a balanced modulator.*

(a) Draw a circuit diagram.
(b) Explain with the aid of waveform sketches the operation of the circuit.
(c) Derive an expression for the output voltage when a signal of the form $e_m = E_m \sin \omega_m t$ modulates a carrier of the form $e_c = E_c \sin \omega_c t$.

A2 *(a)* Sketch *(a)* shows a typical Cowan-type balanced modulator.



(a)

(b) The Cowan balanced modulator shown in sketch *(a)* uses a diode bridge which is switched by the carrier signal. For correct operation, the carrier voltage must be large compared with the audio modulating signal voltage. During one half cycle of the carrier, point (1) on the diode bridge is positive with respect to point (2). During this time, the diodes are forward biased and the bridge presents a virtual short circuit across the audio signal path. During the next half cycle of the carrier, point (2) is positive with respect to point (1), and the diodes are reverse biased. During this time, the bridge presents a virtual open circuit across the audio signal path, and the audio signal passes unhindered to the output transformer. In effect, the audio signal shown in sketch *(b)(i)* is chopped by the switching action of the diode bridge. For ideal diodes, the switching function takes the form shown in sketch *(b)(ii)*. The output signal (sketch *(b)(iii)*) is the result of multiplying the audio signal by the switching function. The output signal contains components at the audio frequency f_{m}, the upper side frequency $(f_{\mathrm{c}} + f_{\mathrm{m}})$, the lower side frequency $(f_{\mathrm{c}} - f_{\mathrm{m}})$ and higher-order frequencies of the form $(2n - 1)f_{\mathrm{c}} \pm f_{\mathrm{m}}$ where n is an integer. Ideally, there is no component at the carrier frequency f_{c}.

(c) For a carrier of the form $e_{\mathrm{c}} = E_{\mathrm{c}} \sin(\omega_{\mathrm{c}} t)$, a Cowan modulator produces a switching function $v(t)$ which can be written as:

$$v(t) = A\left[\frac{1}{2} + \frac{2}{\pi}\{\sin(\omega_{\mathrm{c}} t) + \tfrac{1}{3}\sin(3\omega_{\mathrm{c}} t) + \tfrac{1}{5}\sin(5\omega_{\mathrm{c}} t) + \cdots \text{ etc.}\}\right],$$

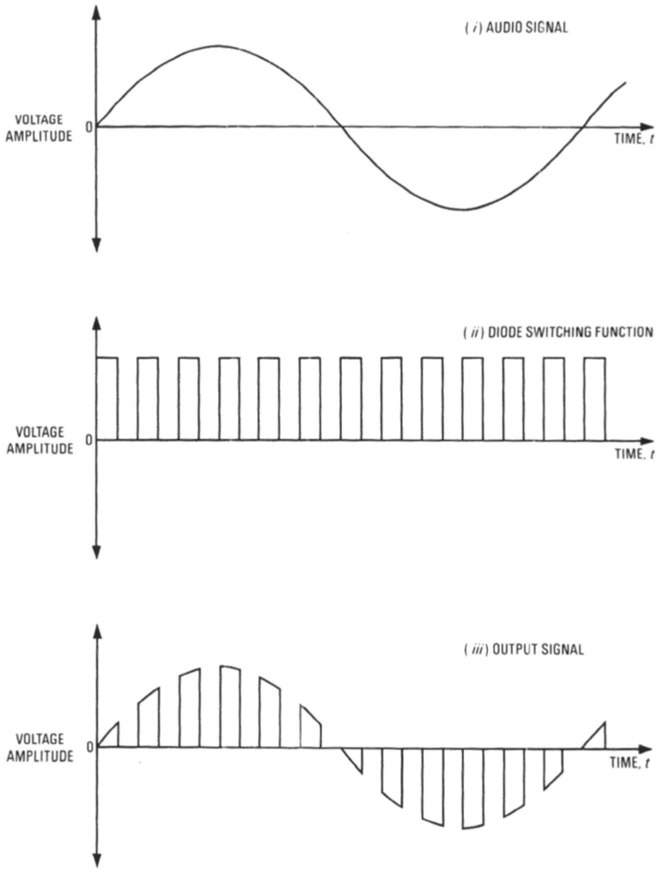
where A is a constant.

The instantaneous voltage of the output signal e_{o} is the product of the audio signal e_{m} and the switching function $v(t)$.

Hence,

$$e_{\mathrm{o}} = e_{\mathrm{m}} v(t).$$

$$e_{\mathrm{o}} = E_{\mathrm{m}} \sin(\omega_{\mathrm{m}} t) A\left[\frac{1}{2} + \frac{2}{\pi}\{\sin(\omega_{\mathrm{c}} t) + \tfrac{1}{3}\sin(3\omega_{\mathrm{c}} t) + \tfrac{1}{5}\sin(5\omega_{\mathrm{c}} t) + \cdots\}\right]$$



(b)

$$= \frac{A}{2} E_{\mathrm{m}} \sin(\omega_{\mathrm{m}} t) + \frac{2A}{\pi} E_{\mathrm{m}}\{\sin(\omega_{\mathrm{c}} t)\sin(\omega_{\mathrm{m}} t) + \tfrac{1}{3}\sin(3\omega_{\mathrm{c}} t)\sin(\omega_{\mathrm{m}} t) + \tfrac{1}{5}\sin(5\omega_{\mathrm{c}} t)\sin(\omega_{\mathrm{m}} t) + \cdots \text{ etc.}\}.$$

Expanding, using the identity

$$\sin A \sin B = \tfrac{1}{2}\cos(A - B) - \tfrac{1}{2}\cos(A + B),$$

and writing C for $\dfrac{A}{2} E_{\mathrm{m}}$ and D for $\dfrac{2A}{\pi} E_{\mathrm{m}}$ gives

$$e_{\mathrm{o}} = C\sin(\omega_{\mathrm{m}} t) + \frac{D}{2}\cos\{(\omega_{\mathrm{c}} - \omega_{\mathrm{m}})t\} - \frac{D}{2}\cos\{(\omega_{\mathrm{c}} + \omega_{\mathrm{m}})t\} + \frac{D}{6}\cos\{(3\omega_{\mathrm{c}} - \omega_{\mathrm{m}})t\} - \frac{D}{6}\cos\{(3\omega_{\mathrm{c}} + \omega_{\mathrm{m}})t\} + \cdots \text{ etc.}$$

The higher-order components at $(3\omega_{\mathrm{c}} \pm \omega_{\mathrm{m}})$, $(5\omega_{\mathrm{c}} \pm \omega_{\mathrm{m}})$, etc., and the audio component at ω_{m}, can be filtered out to leave the two side frequency components $(f_{\mathrm{c}} \pm f_{\mathrm{m}})$.

Q3 *For single-sideband (SSB) transmission systems.*

(a) Explain why SSB is preferred to double sideband (DSB) systems.
(b) (i) Draw a block diagram of a typical transmitter.
(ii) Explain the operation of the system.

Q4 *(a) For a frequency-modulated wave, explain the terms*

(i) rated system deviation
(ii) pre-emphasis and de-emphasis.

(b) Derive, from first principles, an expression for a carrier phase modulated by a sinusoidal signal.

(c) A carrier wave is phase modulated by a 10 kHz signal, the phase deviation is 160°. Find the corresponding frequency deviation.

A4 (*a*)

(*b*) In phase modulation, the phase of the carrier signal is varied in accordance with the modulating signal. The instantaneous voltage of a sine-wave carrier can be written as

$$v_c = V_c \sin(\omega_c t + \phi_0),$$

where V_c is the peak amplitude of the carrier,
ω_c is the angular frequency of the carrier, and
ϕ_0 is some arbitrary angle.

When the carrier is phase modulated, the instantaneous voltage of the pulse-modulated signal becomes

$$v = V_c \sin(\omega_c t + \phi_0 + \Delta\phi),$$

where $\Delta\phi$ is the phase deviation due to the modulating signal. For a sinusoidal modulating signal, $v_m = V_m \sin(\omega_m t)$, the phase deviation can be written as $\Delta\phi = k v_m = k V_m \sin(\omega_m t)$, where k is the phase-angle variation in radians per volt. By defining the peak phase deviation as $\Phi_d = k V_m$ and equating the arbitrary phase ϕ_0 to zero, the instantaneous voltage of a phase-modulated wave can be written as:

$$v = V_c \sin[\omega_c t + \Phi_d \sin(\omega_m t)].$$

(*c*)
$$\omega = \frac{d\theta}{dt}.$$

For a phase-modulated signal, $\theta = \omega_c t + \Phi_d \sin(\omega_m t)$.

Hence, $\omega_i = \omega_c + \omega_m \Phi_d \cos(\omega_m t)$, where ω_i is the instantaneous angular frequency and $\omega_m \Phi_d \cos(\omega_m t)$ is the instantaneous angular frequency deviation.

Here, $\omega_m = 2\pi f_m = 2\pi \times 10 \times 10^3$ rad/s and a phase deviation of 160° is 2·79 radians. Therefore, the frequency deviation is

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{\omega_m \Phi_d}{2\pi} = \frac{2\pi \times 10 \times 10^3 \times 2{\cdot}79}{2\pi} = \underline{27{\cdot}9\ \text{kHz}}.$$

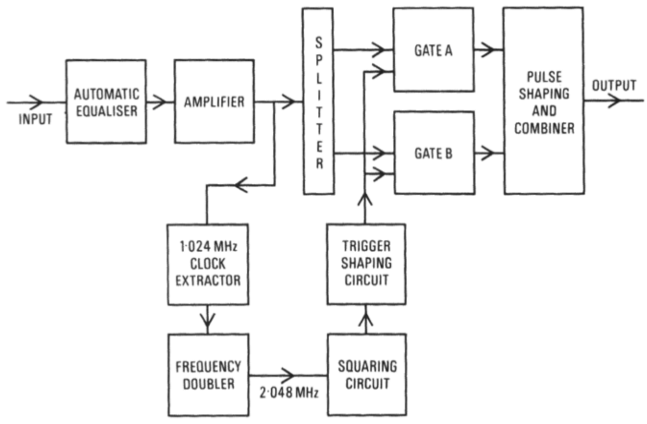
Q5 For a pulse code modulation (PCM) system.

(a) Explain the need for pulse regeneration.
(b) Draw the block diagram of a PCM regenerator.
(c) Explain fully the action of the regenerator.
(d) State a typical distance between PCM regenerators.

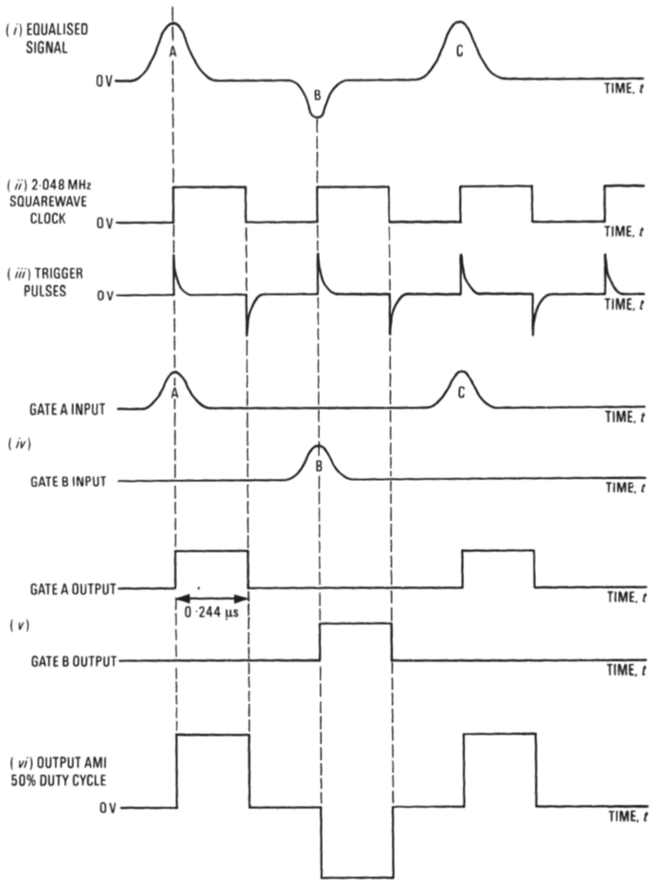
A5 (*a*) PCM signals transmitted over practical links are subject to distortion due to noise and bandwidth limitations. The attenuation and phase characteristics of the link cause rounding off, elongation and tilt of the PCM pulses. Regenerators are employed at fixed distances along the link to reshape/retime the PCM signal.

(*b*) See sketch (*a*).

(*c*) The distorted AMI signal is applied to an automatic equaliser which compensates for line amplitude/phase distortion. After amplification, the equalised signal (sketch (*b*)(*i*)) passes to the timing circuits and the splitter. The first stage of the timing circuit extracts the fundamental bit stream frequency, typically 1·024 MHz for a standard 30-channel system. The resultant sinewave timing signal is doubled in frequency to 2·048 MHz and converted to square wave form by the squaring circuit (sketch (*b*)(*ii*)). The trigger circuit differentiates the 2·048 MHz square wave to produce



(*a*)



(*b*)

positive and negative going trigger pulses. The positive and negative-going pulses of the equalised input signal are separated by the splitter to produce input signals for the two gates (sketch (*b*)(*iv*)). The gates open when signals above a certain threshold and positive-going trigger pulses are both present. The negative-going trigger pulses terminate the gate outputs, which are now in the form of 0·244 μs pulses (sketch (*b*)(*v*)). The gate outputs are reshaped and combined to form the required AMI 50% duty cycle output signal (sketch (*b*)(*vi*)).

(*d*) The distance separating regenerators is typically 1·8 km for a conventional cable link.

Q6 A pulse-width modulation (PWM) system can handle sinusoidal signals of maximum amplitude 25 V and maximum frequency 10 kHz.

(a) Determine

(i) the minimum sampling rate
(ii) the maximum pulse duration.

(b) The system is used to sample a 5 kHz sinusoidal signal of 10 V peak.

(i) Sketch the sine wave to be sampled.
(ii) Beneath this, and to the correct time scale, plot the pulse train that will result.

The duration of each pulse must be indicated.

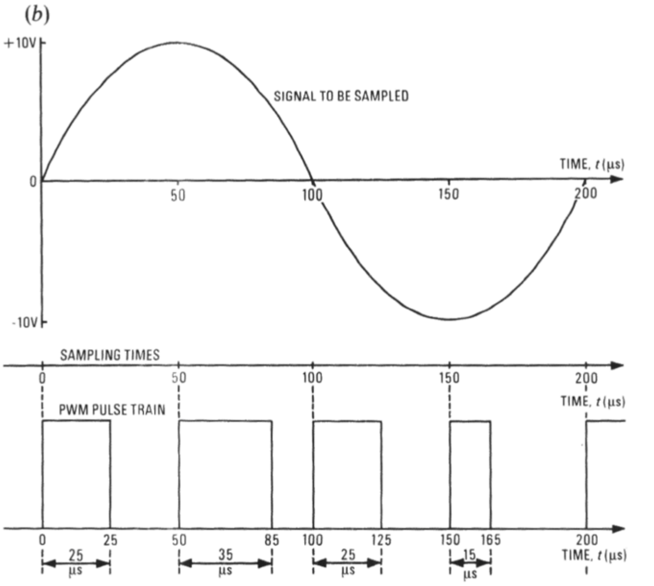
A6 (*a*) (*i*) The minimum sampling rate is twice per cycle of the highest information signal frequency; that is,

$$2 \times 10 \times 10^3 = \underline{20 \times 10^3} \text{ samples per second}.$$

(*ii*) The maximum pulse duration $= \dfrac{1}{\text{minimum sampling rate}}$,

$$= \frac{1}{20\,000}\ \text{s}, \quad = \underline{50\ \mu\text{s}}.$$

(*b*)



Q7 For a time-divided switching system.

(*a*) *Explain with the aid of sketches why it is necessary to switch in both time and space.*

(*b*) *State the need for time-slot interchanging.*

(*c*) *Explain with the aid of a sketch how time-slot interchanging may be accomplished.*

Q8 For a data transmission system

(*a*) *explain the terms*

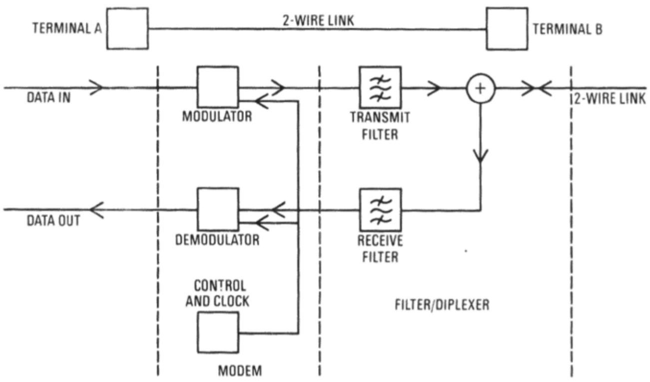
(*i*) *simplex*
(*ii*) *half duplex*
(*iii*) *full duplex.*

(*b*) *Explain, with the aid of a circuit diagram, the operation of a full duplex data system.*

(*c*) (*i*) *Explain the need for error control of a signal.*
(*ii*) *Explain* ONE *method of error control.*

A8 (*a*) (*i*) Transmission is possible in only one direction.
(*ii*) Transmission is possible in both directions but not simultaneously.
(*iii*) Simultaneous transmission is possible in both directions.
(*b*) See sketch.

The full-duplex system shown in the sketch uses frequency-shift-keying (FSK) techniques to separate the transmit and receive signals in frequency. Both terminals employ the same hardware; however, the terminals employ different FSK frequencies. The data to be transmitted from terminal A (the originator) is converted into FSK form by the modem modulator stage. During the time digit 0 (SPACE) is transmitted, the modulator outputs a 1070 Hz sine wave signal; for digit 1 (MARK), a frequency of 1270 Hz is used. For data transmitted from terminal B (the called terminal), a different set of FSK frequencies is used: 2025 Hz for digit 0, and 2225 Hz for digit 1. The two transmissions are separated in frequency and the total bandwidth of the full-duplex transmission lies within the pass-band of the public telephone network. The MARK/SPACE separation of 200 Hz is sufficient to support signalling rates of up to 300 baud. Transmit and receive filters are used to separate the transmit and receive signals at each terminal. Demodulators convert the received FSK signals back into binary-coded data signals.



(*c*) (*i*) Data signals are used to communicate specific information; for example, bank statements, where an undetected error could significantly change the information content of the data. Error detection and correction facilities are therefore necessary to maintain the standard of service.

(*ii*) One method of error control is to use exact count coding and automatic retransmission request (ARQ) techniques.

The data to be transmitted is encoded into an exact count code, where each code group has a specified number of digit 1s. For example, each code group could consist of 7 bits, three of which are digit 1s. At the receive end, an electronic count of the digit 1s in each code group is performed. Any group where the count is not exactly three is in error, and an automatic request for retransmission is initiated.

Q9 For a packet switching system

(*a*) *explain the need for such a system*
(*b*) *draw a typical system*
(*c*) *explain*

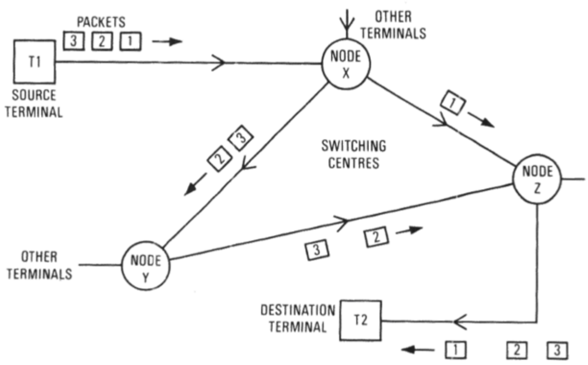
(*i*) *the principle of 'store and forward'*
(*ii*) *a typical message format.*

A9 (*a*) The increasing amount of information transmitted over telecommunication networks has made it necessary to optimise the use of the transmission facilities available. The packet switching system with its store-and-forward facility, where packets are switched in a statistically concentrated manner, is one method of optimising the use of distributed networks.

(*b*) See sketch (*a*).

(*c*) (*i*) As each packet is received at a switching centre, it is stored in an electronic memory facility. The packet is checked for errors and stored along with other packets until a circuit is available for onward transmission. Packets of the same message may not be forwarded via the same route.

(*c*) (*ii*) Each message is broken down into a series of numbered packets. Each packet is subdivided into two main sections: the header section, which contains supervisory data, and the text section, which contains the message text data. A typical packet format is shown in sketch (*b*). The start flag bits indicate the start of the package and provide synchronisation. The next two parts of the header identify the source and destination addresses. Control bits are included to indicate the type of text transmitted; that is, acknowledgement or message text. The next sections identify the message and the packet number. The text portion is followed by the error detection bits.



(*a*)

START FLAG	SOURCE ADDRESS	DESTIN-ATION ADDRESS	CONTROL INFOR-MATION	MESSAGE NUMBER	PACKET NUMBER	TEXT BITS	ERROR CONTROL BITS

HEADER

(*b*)

Students were required to answer any six questions. The time allowed was three hours. Students are advised to read the notes on p. 5

Q1 (*a*) *A 200 V 500 Hz supply is connected to a component. The consequent current has a magnitude of 50 mA and lags the supply voltage by 65°. Determine for the component*

(*i*) *the impedance*
(*ii*) *the admittance.*

(*b*) *Calculate the values of the two ideal elements which can represent the component in* (*a*) *when the elements are*

(*i*) *in series*
(*ii*) *in parallel.*

Q2 (*a*) *A 350 μH coil has a Q-factor of 120 at a frequency of 25 kHz. For parallel resonance at 25 kHz determine*

(*i*) *the circuit capacitance*
(*ii*) *the impedance of the resonant circuit*
(*iii*) *the 3 dB bandwidth.*

(*b*) *The parallel tuned circuit in* (*a*) *is connected to a 150 mV, variable-frequency source through a 10 kΩ resistor. Calculate*

(*i*) *the potential difference across the tuned circuit when the frequency is 25 kHz;*
(*ii*) *the frequencies at which this potential difference is 3 dB below its value at 25 kHz.*

A2 (*a*) (*i*) Since the Q-factor of the circuit is greater than 10, the formula

$$f_0 = \frac{1}{2\pi\sqrt{(LC)}}$$

can be used to relate the resonant frequency f_0 to the inductance L and capacitance C.

Transposing the equation,

$$C = \frac{1}{4\pi^2 f_0^2 L}.$$

Substituting values gives

$$C = \frac{1}{4\pi^2 \times (25 \times 10^3)^2 \times 350 \times 10^{-6}},$$

$$= \underline{1{\cdot}16 \times 10^{-7}\ \mathrm{F}}.$$

(*ii*) The impedance of the resonant circuit is the dynamic resistance R_D, which is related to the Q-factor and the individual reactances by

$$R_D = QX_0,$$

where X_0 is the reactance at resonance of either the inductance or the capacitance of the circuit.

Using the inductance,

$$R_D = Q\omega_0 L = 120 \times 2\pi \times 25 \times 10^3 \times 350 \times 10^{-6},$$

$$= \underline{6600\ \Omega}.$$

[*Tutorial Note:* An alternative method is to use the relation

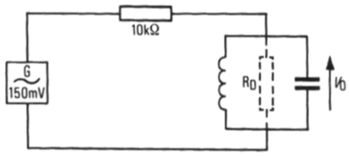
$$R_D = \frac{L}{CR_s},$$

where R_s is the series resistance of the coil. R_s can be calculated from $Q = \omega_0 L/R_s$ and R_D obtained by substitution. This method takes longer, and, if an error occurred in the calculation of C, this would carry forward to the calculation of R_D.]

(*iii*) The 3 dB bandwidth is obtained from

$$3\text{ dB bandwidth} = \frac{f_0}{Q} = \frac{25 \times 10^3}{120} = \underline{208\ \mathrm{Hz}}.$$

(*b*) The circuit arrangement is as shown in the sketch.



(*i*) At 25 kHz, the tuned circuit impedance is resistive with value $R_D = 6600\ \Omega$.

By using the potential divider rule,

$$V_0 = 150 \times 10^{-3} \times \frac{6600}{10\,000 + 6600} = \underline{59{\cdot}6\ \mathrm{mV}}.$$

(*ii*) The effective Q-factor of the tuned circuit is modified by the 10 kΩ resistance in series with the source. The effective tuned circuit parallel resistance becomes $R_E = R_D$ in parallel with 10 kΩ.

Hence,

$$R_E = \frac{10\,000 R_D}{R_D + 10\,000} = \frac{6600 \times 10\,000}{16\,600},$$

$$= 3980\ \Omega.$$

The effective Q-factor, Q_E,

$$= 120 \times \frac{3980}{6600} = 72{\cdot}4.$$

The consequent 3 dB bandwidth

$$= \frac{f_0}{72{\cdot}4} = \frac{25\,000}{72{\cdot}4} = 345\ \mathrm{Hz}.$$

The 3 dB frequencies are then

$$25\,000 \pm \frac{345}{2} = \underline{25\,172\ \mathrm{Hz\ and}\ 24\,828\ \mathrm{Hz}}.$$

Q3 (*a*) *For the circuit in Fig. 1 below, determine by application of Thévenin's theorem or otherwise the magnitude of the current in the 800 Ω resistor.*

(*b*) *A 200 Ω resistor is connected in parallel with the 800 Ω resistor in Fig. 1. Calculate the current in the 200 Ω resistor.*

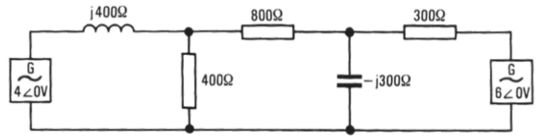
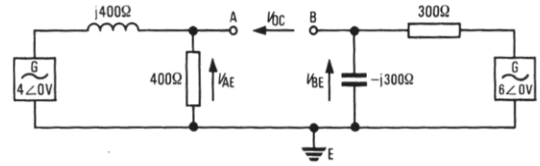


Fig. 1

A3 (*a*) To obtain the appropriate Thévenin equivalent circuit, remove the 800 Ω resistor and determine the open circuit voltage and impedance looking back for the terminals from which the resistor has been removed. These are A and B in the circuit shown in sketch (*a*).



(*a*)

The open-circuit voltage V_{oc} is given by

$$V_{oc} = V_{AE} - V_{BE}.$$

By the potential divider rule,

$$V_{AE} = 4 \times \frac{400}{400 + j400},$$
$$= \frac{4}{1+j},$$
$$= \frac{4}{2}(1 - j),$$
$$= 2 - j2\ \text{V}.$$

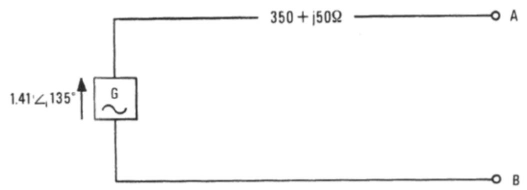
Similarly,

$$V_{BE} = \frac{6 \times (-j300)}{300 - j300},$$
$$= \frac{6 \times (-j)}{1 - j},$$
$$= \frac{-6j(1+j)}{2},$$
$$= -j3 + 3,$$
$$= 3 - j3.$$
$$\therefore \quad V_{oc} = 2 - j2 - (3 - j3)$$
$$= -1 + j = 1{\cdot}41 \angle 135°\ \text{V}.$$

The impedance looking back from AB is given by

$$Z_{AB} = (400 \text{ in parallel with } j400) + (300 \text{ in parallel with } -j300),$$
$$= \frac{400 \times j400}{400 + j400} + \frac{300(-j300)}{300 - j300},$$
$$= \frac{j400}{1+j} + \frac{(-j300)}{1-j},$$
$$= \frac{j400(1-j)}{2} - \frac{j300}{2}(1+j),$$
$$= j200 + 200 - j150 + 150$$
$$= 350 + j50\ \Omega.$$

The Thévenin equivalent circuit is shown in sketch (*b*).



(*b*)

The current in the 800 Ω replaced across AB is given by

$$I = \frac{1{\cdot}41 \angle 135°}{1150 + j50} = \frac{1{\cdot}41 \angle 135°}{1151 \angle 2{\cdot}5°}$$

Hence, the magnitude of $I = 1{\cdot}41/1151 = 1{\cdot}23$ mA.

(*b*) With 200 Ω in parallel with the 800 Ω resistor, the effective resistance is

$$\frac{200 \times 800}{200 + 800} = 160\ \Omega.$$

The current through the parallel combination is

$$I = \frac{1{\cdot}41 \angle 135°}{510 + j50} = \frac{1{\cdot}41 \angle 135°}{512 \angle 5{\cdot}6°}.$$

The magnitude of the current $= 1{\cdot}41/512 = 2{\cdot}75$ mA.

(*b*) By using the current divider rule, the current in the 200 Ω resistor is

$$2{\cdot}75 \times \frac{800}{200 + 800} = 2{\cdot}20\ \text{mA}.$$

Q4 *(a) A load is connected to a source which has a complex internal impedance. State the conditions for maximum power transfer to the load if*

(i) the load comprises both resistance and reactance
(ii) the load is resistive only.

(b) A source has an open-circuit voltage of 3 V at a frequency of 2 kHz and an internal impedance equivalent to a resistance of 600 Ω in series with an inductance of 15 mH.

Calculate the values of the load components which will take maximum power from the source.

(c) For the source in (b), calculate

(i) the maximum load power
(ii) the power dissipated in the source
(iii) the efficiency of power transfer.

A4 (*a*) (*i*) The load impedance must be the complex conjugate of the source impedance.

(*ii*) The load resistance must equal the magnitude of the source impedance.

(*b*) The source impedance $Z_s = R_s + j\omega L_s$.

Substituting values,

$$Z_s = 600 + j2\pi \times 2 \times 10^3 \times 15 \times 10^{-3},$$
$$= 600 + j188{\cdot}5\ \Omega.$$

The load impedance for maximum power transfer from source to load is the complex conjugate of the source impedance; that is,

$$\text{load impedance} = 600 - j188{\cdot}5\ \Omega.$$

The components to provide this impedance are a 600 Ω resistor in series with a capacitor with a reactance of 188·5 Ω; that is,

$$\frac{1}{\omega C} = 188{\cdot}5\ \Omega.$$
$$C = \frac{1}{2\pi f \times 188{\cdot}5},$$
$$= \frac{1}{2\pi \times 2 \times 10^3 \times 188{\cdot}5},$$
$$= 0{\cdot}422\ \mu\text{F}.$$

The load components are thus a 600 Ω resistor in series with a 0·422 μF capacitor.

(*c*) (*i*) The maximum load power

$$P = \frac{E^2}{4R_s},$$

where E is the source EMF and R_s is the source resistance.

Substituting values,

$$P = \frac{3^2}{4 \times 600} = \frac{9}{2400} = 3{\cdot}75\ \text{mW}.$$

(*ii*) Since the source resistance is the same as the load resistance and it carries the same current, the power dissipated in the source is also 3·75 mW.

(*iii*) The efficiency of power transfer is

$$\frac{\text{load power}}{\text{load power + source power}} = \frac{3{\cdot}75}{7{\cdot}5} = 50\%.$$

Q5 *(a) Explain why, in AC circuits, power calculations cannot always be made by multiplication of the RMS values of current and voltage.*

(b) The potential difference across a circuit component is (20 + j15) V when the current is (3 − j1) A.

(i) Determine the power dissipated in the component using the formula $P = VI\cos\phi$.

(ii) With reference to a phasor diagram, show how the power could be calculated directly from the cartesian forms of the voltage and current.

A5 (*a*) In AC circuits the product of the RMS values of current and voltage gives the apparent power in volt-amperes. To obtain the actual power, the apparent power must be multiplied by the power factor. The power factor can have a value between zero and unity. For sinusoidal current and voltage, the power factor is given by the cosine of the phase difference between current and voltage.

(*b*) (*i*) To determine the power, the magnitude of the voltage and current are required, together with ϕ, the phase angle between them. First the quantities are converted to the polar form.

$$V = (20 + j15) = \sqrt{\{(20)^2 + (15)^2\}} \angle \tan^{-1}\frac{15}{20},$$

$$= \sqrt{400 + 225\}} \angle \tan^{-1} 0{\cdot}75,$$

$$= 25 \angle 36{\cdot}9^\circ \text{ V}.$$

Similarly $I = (3 - j1) = 3{\cdot}16 \angle -18{\cdot}4^\circ$ ampere.

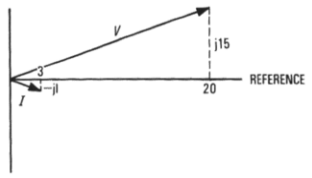
The phase angle between V and I

$$= 36{\cdot}9^\circ - (-18{\cdot}4^\circ) = 55{\cdot}3^\circ.$$

Power, P,

$$= VI\cos\phi = 25 \times 3{\cdot}16\cos(55{\cdot}3^\circ) = \underline{45 \text{ W}}.$$

(*ii*) The phasor diagram is shown in the sketch.



Power = product of real components

+ product of quadrature components,

$$= 20 \times 3 + 15 \times (-1),$$

$$= 60 - 15 = \underline{45 \text{ W}}.$$

Q6 *(a) Explain*

(i) the two main causes of power loss in ferro-magnetic materials
(ii) why each type of loss varies with frequency
(iii) the measures which can be taken to minimise these losses.

(b) An iron-cored coil is connected to a constant-voltage variable frequency supply. For frequency of 50 Hz, the power loss in the iron is found to be 1·2 W and the loss rises to 4·3 W at a frequency of 100 Hz. Estimate the power loss for a frequency of 150 Hz.

Q7 *(a) Explain the following terms as applied to dielectrics*

(i) permittivity
(ii) dielectric hysteresis
(iii) breakdown strength (dielectric strength).

(b) Explain why capacitors with the same value of capacitance can be obtained in a wide range of physical sizes.

(c) A 0·5 μF capacitor has a loss-angle of 6×10^{-4} rad when it is connected to an 8 V, 7 kHz supply. Calculate

(i) the current taken from the supply
(ii) the equivalent series resistance
(iii) the power loss.

A7 (*a*) (*i*) Permittivity relates the electric field E in a dielectric to the displacement D in the formula $D = \varepsilon E$ where ε is the permittivity.

[*Tutorial Note:* E is the electrical stress in volts per metre, and D is the charge density in coulomb per square metre.]

(*ii*) When a potential difference is applied across a dielectric, the electric field distorts the internal structure. Under alternating conditions, these distortions pass through cycles, and in each cycle some energy is dissipated. This internal distortion is called *dielectric hysteresis.*

(*iii*) The breakdown strength of a dielectric is the maximum electric field which can be supported by the dielectric. If the field exceeds the breakdown strength, the dielectric breaks down.

(*b*) Capacitors with the same value of capacitance have different sizes for two main reasons:

(*i*) **Type of Dielectric**
Capacitance is proportional to the permittivity of the dielectric, and so for high permeability, capacitors are smaller than for low permeability.

(*ii*) **Working Voltage**
The electric field is the applied voltage divided by the thickness of the dielectric. For a given material, the thickness of the dielectric is proportional to the applied voltage at the breakdown strength. Thus for low working voltages the dielectric can be thin and the capacitor small.

(*c*) The reactance of the capacitor is

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 7000 \times 0{\cdot}5 \times 10^{-6}},$$

$$= 45{\cdot}5\,\Omega.$$

Therefore:

(*i*) Current $= \dfrac{V}{X_C} = \dfrac{8}{45{\cdot}5} = 0{\cdot}176$ A.

(*ii*) Series resistance, R_s,

$$= \text{loss angle} \times X_C,$$

$$= 6 \times 10^{-4} \times 45{\cdot}5,$$

$$= \underline{0{\cdot}0273\,\Omega}.$$

(*iii*) Power loss

$$= I^2 R_s = (0{\cdot}176)^2 \times 0{\cdot}0273 \text{ W} = \underline{846\,\mu\text{W}}.$$

Q8 *(a) An open-wire loss-free line has a characteristic resistance of 600 Ω. Taking the velocity of propagation as 3×10^8 m/s calculate*

(i) the inductance per metre
(ii) the capacitance per metre.

(b) The line in (a) is terminated in a 400 Ω resistor and supplied by a 25 MHz source.

(i) Calculate the reflection coefficient at the termination.
(ii) Explain briefly how standing waves will be created on the line.
(iii) Determine the distance between successive maxima.
(iv) Determine the distance between a maximum and the next minimum.

A8 (*a*) Characteristic impedance Z_0 and velocity of propagation v_p are related to the inductance per unit length, L, and the capacitance per unit length, C, by

$$Z_0 = \sqrt{\left(\frac{L}{C}\right)}, \qquad \ldots\ldots(1)$$

and

$$v_p = \frac{1}{\sqrt{(LC)}}. \qquad \ldots\ldots(2)$$

Transposing these formulae to give L and C in terms of Z_0 and v_p can be achieved as follows. Multiplying Z_0 by v_p on both sides of equations (1) and (2) gives

$$Z_0 v_p = \sqrt{\left(\frac{L}{C}\right)}\frac{1}{\sqrt{(LC)}} = \frac{1}{C}$$

$$\therefore \quad C = \frac{1}{v_p Z_0}. \qquad \ldots\ldots(3)$$

Dividing Z_0 by v_p in a similar manner gives

$$\frac{Z_0}{v_p} = \sqrt{\left(\frac{L}{C}\right)} \frac{1}{\dfrac{1}{\sqrt{(LC)}}} = \sqrt{\left(\frac{L}{C}\right)} \sqrt{(LC)} = L.$$

Thus,

$$L = \frac{Z_0}{v_p}. \qquad \ldots\ldots (4)$$

Substituting the values of Z_0 and v_p in equations (3) and (4) gives

$$L = \frac{600}{3 \times 10^8} = \underline{2\,\mu\text{H/m}},$$

and

$$C = \frac{1}{3 \times 10^8 \times 600} = \underline{5{\cdot}5\ \text{pF/m}}.$$

(*b*) (*i*) The voltage reflection coefficient

$$\rho = \frac{Z_T - Z_0}{Z_T + Z_0},$$

where Z_T is the terminating resistance.
Hence

$$\rho = \frac{400 - 600}{400 + 600} = \underline{-0{\cdot}2}.$$

(*ii*) Examining the incident and reflected waves from the termination towards the source, the incident wave has a constant value and a leading phase proportional to the distance from the termination. The reflected wave of a different constant value has a lagging phase proportional to distance. The voltage at a particular point is the phasor sum of the incident and reflected waves. The voltage varies between maximum values when incident and reflected wave are in phase, and minimum values when the waves are in antiphase, so producing a standing wave.

(*iii*) Successive maxima are separated by a half wavelength. The wavelength, λ, is given by

$$\lambda = \frac{v_p}{f},$$

where f is the frequency.
In this case,

$$\lambda = \frac{3 \times 10^8}{25 \times 10^6} = 12\ \text{m}.$$

Distance between successive maxima = 12/2 = $\underline{6\ \text{m}}$.

(*iv*) The distance between a maximum and the next minimum is a quarter-wavelength, and in this case is equal to 12/4 = $\underline{3\ \text{m}}$.

Q9 (*a*) *State what is meant by*

(*i*) *characteristic impedance*
(*ii*) *insertion loss*

of an attenuator.

(*b*) *Calculate the characteristic impedance of the attenuator in Fig. 2.*

(*c*) *Calculate the insertion loss due to the network in Fig. 3 when it is connected between a 300 Ω source and a 300 Ω load.*

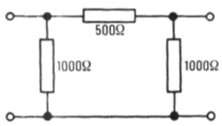


Fig. 2

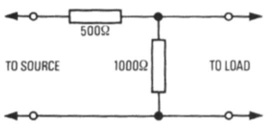


Fig. 3

A9 (*a*) (*i*) The characteristic impedance of an attenuator is the impedance measured at one port when the other port is closed in that same impedance.

(*ii*) The insertion loss of an attenuator is the ratio, expressed in decibels, of the current in the load without the attenuator, I_1, to the current in the load, I_2, with the attenuator inserted; that is,

$$\text{insertion loss} = 20 \log_{10} \frac{I_1}{I_2}.$$

(*b*) The characteristic impedance, Z_0, is given by the relation

$$Z_0 = \sqrt{(Z_{sc} Z_{oc})},$$

where Z_{sc} and Z_{oc} are the input impedances with the output short circuited and open circuited, respectively.
In this case,

$$Z_{sc} = 1000\ \Omega \text{ in parallel with } 500\ \Omega.$$

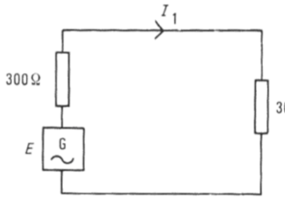
$$= \frac{1000 \times 500}{1000 + 500} = \frac{5000}{15} = 333{\cdot}3\ \Omega.$$

$$Z_{oc} = 1000\ \Omega \text{ in parallel with } 1500\ \Omega.$$

$$= \frac{1000 \times 1500}{1000 + 1500} = 600\ \Omega.$$

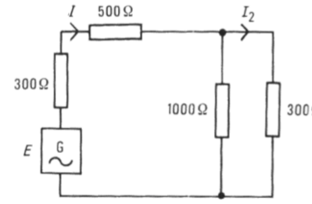
$$\therefore \quad Z_0 = \sqrt{(333{\cdot}3 \times 600)} = \underline{447\ \Omega}.$$

(*c*) Consider the circuits with and without the network, see sketches (*a*) and (*b*).



WITHOUT NETWORK

(*a*)



WITH NETWORK

(*b*)

From sketch (*a*),

$$I_1 = \frac{E}{600}. \qquad \ldots\ldots (1)$$

From sketch (*b*),

$$E = 1800I - 1000I_2 \qquad \ldots\ldots (2)$$

$$0 = 1000I - 1300I_2. \qquad \ldots\ldots (3)$$

From equation (3), $I = 1{\cdot}3I_2$.
Substituting into equation (2) gives

$$E = 1800 \times 1{\cdot}3I_2 - 1000I_2,$$

$$= 2340I_2 - 1000I_2 = 1340I_2.$$

$$\therefore \quad I_2 = \frac{E}{1340}.$$

$$\therefore \quad \frac{I_1}{I_2} = \frac{E}{600} \times \frac{1340}{E} = \frac{1340}{600} = 2{\cdot}23.$$

The insertion loss = $20 \log_{10} 2{\cdot}23 = \underline{6{\cdot}98\ \text{dB}}$.

Q10 (*a*) *Define the y-parameters of a two-port network.*

(*b*) *Determine the y-parameters of the two-port network in Fig. 4 (below).*

(*c*) *The network shown in Fig. 4 has a 200 Ω resistor connected across the output and a constant voltage of 2 V is applied to the input. Use the y-parameters to determine*

(*i*) *the input current*
(*ii*) *the output current.*

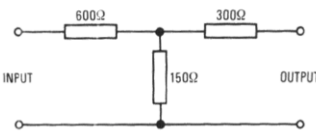


Fig. 4

Answers contributed by L. J. Colenutt

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